Report for 2001FL4341B: Flow Duration Curves to Advance Ecologically Sustainable Water Management

- unclassified:
  - Good, J. C., and J. M. Jacobs, 2001, Ecologically Sustainable Watershed Management using Annualized Flow Duration Curves, ASCE World Water and Environmental Resources Congress, Orlando, FL, May. (paper reviewed by conference committee).
  - Jacobs, J. M., and G. Ripo, 2001, Minimum Flows and Levels for the Lower Suwannee River-Implementation and Methodology. University of Florida, Gainesville, Florida, June, 129 pages.
  - Good, J. C., and J. M. Jacobs, 2001, Use of Annualized Flow Duration Curves for Minimum Flows Levels. Florida Section ASAE Annual Conference, Orlando, Florida, Cocoa Beach, Florida, May 10-11.
  - Jacobs, J. M., and J. C. Good, 2000, Application of Annualized Flow Duration Curves to Minimum Water Flows and Levels, Proceedings of the American Geophysical Union 2000 Spring Meeting, Washington, DC.

Report Follows:

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Title: Flow Duration Curves to Advance Ecologically Sustainable Water Management

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Problem and Research Objectives:

Per Florida Statutes (F.S.), the Florida Water Management Districts and the Florida Department of Environmental Protection are charged with setting minimum surface water flows for water courses. As defined by Section 373.042, F.S., "the minimum flow for a given water course shall be the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." Towards this end, Florida's Water Management Districts have initiated the development of minimum flows and levels (MFLs) for selected rivers and streams in their respective jurisdictions. Recent advances in systems ecology have shown that natural streamflow variability over the full range of flows, drought to flood flows, is critical to the ecosystem dynamics. Thus, the prevention of significant harm to ecosystems needs to address a full regime of flow conditions.

Florida's Statutes are well aligned with current national objectives. The widespread modification and management of river systems has had major ecological impacts in North America. The negative impacts have caused a major change in watershed management. The result of this change is the undoing of many large river engineering projects. Dams are being removed across the country from the Columbia River to northern Maine. More locally, the Kissimmee River in Florida is being restored to its natural channel. Florida is considering removing the Rodham Dam and restoring the Oklawaha River. Efforts to restore the Everglades will take place over the next few decades. Watershed management and planning has changed from focused analysis of water supply diversions, flood protection and hydropower generation to a more holistic view. While much progress has been made in the development of instream flow analysis, a significant gap exists in the hydrological sciences between the research progress and the approaches implemented by practitioners. A demand exists for tools that can support resource managers' and policy makers' new mission. These tools must provide the ability to synthesize ecology with hydrology and to enhance policy design (Walters and Josh, 1999).

The goal of this research was to develop a methodology that uses flow duration curves to accurately, quickly, and easily integrate streamflow data and ecologically significant hydrologic data for the development of minimum flows and levels. Linked ecological and hydrological indicators were used deterministically to adjust the entire range of flows. The outcome of this research is an optimized management system that maximizes available water while sustaining ecosystems. The methodology is the engine for a graphically based analysis and planning tool. This tool is applicable throughout the planning and implementation phase of a MFL program to help policymakers, technical staff, and other interested parties understand the impact of proposed ecological constraints on available streamflow and to validate that the cumulative withdrawals meet the MFLs. An integrated software program that includes a statistical analysis tool for the annual FDCs and FDC modification and inversion routines was created in order to facilitate the application of the methodology and analysis of hydrological responses to proposed changes. The methodology can provide insight for managers of rivers where ecosystem functions are important criteria for river management and restoration.

Methodology:

Three gaging stations along the Suwannee River were analyzed to develop a database necessary for the development of regional minimum flows and levels. The data used was assumed to be stationary and was examined through a time trend analysis. The resulting database was analyzed to develop summaries of hydrologic data and analyses that specifically address the MFL purposes. These analyses included: a determination of seasonality and an appropriate climatic year for segmentation of the data; a frequency analysis to characterize extreme high and low flows; a calculation of a period of record flow duration curve (POR FDC) and annual flow duration curves (AFDCs); an event-duration-frequency analysis to examine flow timing; a determination of indicators of Hydrologic Alteration as prescribed by the Range of Variability Approach; and a fitting of distribution frequencies of inter-annual curves, for a more robust characterization of the complete annual flow regime. Concurrent analysis of precipitation measurements from three long-term precipitation stations was done to characterize the lower basin meteorological data over the complete gaging stations' history.

Having characterized the Suwannee River gages, a methodology was developed that uses flow duration curves to accurately and easily integrate streamflow data and hydrologically significant ecological data for the development of MFLs. This approach integrated ecological and hydrological indicators, which are then used deterministically to adjust the entire range of flows. The outcome of this effort is a set of criteria that maximizes available water while sustaining ecosystems. The developed MFL methodology was compared with two other possible withdrawal scenarios.

Principal Findings and Significance:
Many studies that examine large historic periods of recorded hydrologic data require a method for separating continuous data into independent sets. The common water year is generally accepted as an appropriate separation of data focuses on high flow events. This study focused on the hydrologic effects on the ecology, thereby making a sole examination of maximum events insufficient. The identification of extreme high and low flow events as integral parts of the health of a river ecosystem made it necessary to determine a water year that would not separate annual extreme events. Based upon the analysis of ten extreme annual conditions and their corresponding Julian day of occurrence, the ideal water year for the investigation was found to begin on February 1st and end on January 31st.

The MFL methodology was developed through a unique approach that collectively integrates ecological control points within a flow duration curve framework. In this context a "control point" identifies a specific measure that must be considered for the establishment of instream flows. This framework focuses on the assessment of withdrawals that are sustainable without unacceptable change to the water resources or ecology of the area as opposed to the remediation of unacceptable change. In these cases, two specific measures for the quantification of a control point are required: 1) hydrologic flow measures and 2) allowable flow modifications. These points may result from legislative measures or from ecological investigations that identify flow conditions critical for the ecology and will ultimately provide the basis necessary to determine maximum withdrawal rates.

Flow modifications are performed within the POR FDC allowing for control of timing and magnitudes of withdrawals. The methodology results in graphical tools. Graphs depicting the historic variation in available streamflow, the reliability of available streamflow, and streamflow available for withdrawal versus total streamflow could be used to assess if the proposed withdrawals adequately protect the ecology of the river.

A case study was conducted to demonstrate the application of the methodology to the establishment of MFLs in the lower Suwannee River basin. The study used three control points and allowable shifts that were derived from ecological studies conducted by SRWMD. Each control point addressed a different portion of the flow regime, capturing a range of ecological criteria. The first control point was based upon floodplain inundation and captured a high portion of the flow regime. The second control point addressed the moderate-low in the flow regime and was derived from the location of the freshwater/salinity transition between the Suwannee River and the Gulf of Mexico. The third control point was based upon water supply under drought conditions and represented the lowest portion of the flow regime.

In order to improve the understanding of the FDC allocation methodology, it is contrasted to other allocation approaches. Two other possible withdrawal scenarios were considered in order to identify the effect of the shifting method on the available water: (1) a constant percent flow withdrawal; and (2) a constant flow withdrawal. The withdrawal scenarios were based on the most conservative shift that would result based upon the allowable shifts identified for three control points used. The FDC methodology resulted in a much larger quantity of available water (427.7 mgd) than either a constant percent (2.03.7 mgd) or a constant shift (113.0 mgd). The percent method has a larger firm yield than the constant available flow method because the water available for allocation increases with increasing streamflow. This large difference among the results from the FDC shift being determined with respect to all the control points, allowing for a much larger amount of available water in the median flow regime. The minimum percent and constant withdrawal scenarios are both ecologically conservative. However, neither single criteria methodology was able to allow for the availability of relatively large quantities during median flow conditions.